

Preface	xi
Acknowledgments	xvii
Series Foreword	xix
<b>1 Introduction</b>	<b>1</b>
1.1 Gradual and Compositional Evolution	3
1.2 The Algorithmic Paradigms of Evolution	8
1.3 Complex Systems with Modular Interdependency and Their (Un)evolvability	12
1.4 Compositional Mechanisms	16
1.5 The Impact on Gradualism	19
1.6 Some Related Issues	24
1.7 Contributions	27
<b>2 Gradual Evolution</b>	<b>29</b>
2.1 The Gradualist Framework of Evolution	29
2.2 Evolutionary Algorithms	31
2.3 Concepts of Evolutionary Difficulty	35
2.4 Summary	43
<b>3 Compositional Evolution</b>	<b>45</b>
3.1 Compositional Mechanisms	45
3.2 Models of Composition	55
3.3 Some Issues in the Use of Compositional Mechanisms	81
3.4 Some Conceptual Issues of Compositional Evolution	90
3.5 Summary	97
<b>4 Modularity</b>	<b>101</b>
4.1 Interdependency	103
4.2 Modular Interdependency	109
4.3 Hierarchical Modular Interdependency	117
4.4 Hierarchical-If-and-Only-If (HIFF)	125
4.5 Discussion	129
4.6 Summary	146
<b>5 Mutation</b>	<b>149</b>
5.1 Examining the Fitness Landscape	149
5.2 Difficulty of Modular Interdependency for Gradual Mechanisms	150

5.3	Expected Time to Solution for Gradual Mechanisms	155
5.4	Simulation Results for Mutation	157
5.5	Summary	160
<b>6</b>	<b>Sexual Recombination</b>	163
6.1	Overview of Models	164
6.2	Results for a Single Panmictic Population—The Simple GA	165
6.3	Results for a Subdivided or Niche Population—GA with Crowding	167
6.4	The Dependence on Physical Linkage	174
6.5	The Impact for GA Theory	183
6.6	Summary	185
<b>7</b>	<b>Symbiotic Encapsulation</b>	191
7.1	An Overview of the Symbiotic Encapsulation Model	191
7.2	Entities and Their Encapsulation	193
7.3	Evaluation and Selection	200
7.4	The Symbiogenic Evolutionary Adaptation Model (SEAM)	205
7.5	Simulation Results for Symbiotic Encapsulation	205
7.6	The Relationship of SEAM to Other Algorithmic Methods	210
7.7	Summary	217
<b>8</b>	<b>How Fast Is Fast?</b>	219
8.1	An Analysis of Sexual Recombination on HIFF	219
8.2	An Analysis of SEAM on Shuffled HIFF	234
8.3	Summary	243
<b>9</b>	<b>Scaling Up Evolution</b>	245
9.1	Units in Sexual Populations	247
9.2	Scaling Up Evolution with Symbiotic Encapsulation	255
9.3	The Inherent Tension of Innovation and Reproductive Fidelity	265
<b>10</b>	<b>The Impact of Compositional Evolution</b>	267
10.1	Future and Ongoing Research	267
10.2	Large Directed Adaptive Genetic Changes	274
10.3	Symbiosis as a Source of Evolutionary Innovation	276
10.4	Evolutionary Difficulty and Gradualism	277
10.5	Algorithmic Principles of Adaptation	277

10.6	The Availability and Impact of Compositional Mechanisms in Nature	279
10.7	Modularity in Natural Systems	280
10.8	Conclusions	285
	Notes	291
	Glossary	295
	References	303
	Index	319